COMPARATIVE STUDY OF VTM AND AASHTO TEST METHOD FOR CBR

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1.0 INTRODUCTION

1.1 Background

The California Bearing ratio (CBR) test has been widely used in pavement design since mid 1940's. It is a relative measure of subgrade soil or base/subbase aggregate strength. The Virginia Department of Transportation (VDOT) has been using its own Virginia Test Method-8 (VTM-8) to perform CBR testing. On the other hand, private industry and other DOT's are using AASHTO (American Association of State Highway and Transportation Officials) test method (T 193) to measure CBR. Although there are some differences between these two test procedures, both of them measure the same soil property.

According to Thomas Stanton (Materials and Research Engineer, CA Division of Highways), the Bearing Ratio Test was adopted in California in 1930. VDOT's test method for CBR was first introduced in the Soils Laboratory's (Division of Tests, Virginia Department of Highways) *Virginia's Test Method of Conducting C.B.R. Tests* in January 1952. The current standard VTM-8 follows the original 1952 method exactly. AASHO introduced T 193 in 1963; which was revised and updated by AASHTO in 1972, 1981 and 1999 to meet industry requirements and advances in theory and technology.

The test procedures in AASHTO is internationally recognized and widely used in textbooks, scientific studies and industry literatures. Moreover, they are constantly updated to reflect the knowledge gained from research and field experience. The AASHTO procedure for CBR test is more flexible than Virginia method and it allows the designer to request other information such as CBRs for range of moisture content and density. VDOT is currently equipped to conduct AASHTO version of CBR test in all of its seven soils labs and at least four of these labs are accredited by AASHTO Materials Reference Laboratory (AMRL). Therefore it would be beneficial for VDOT to investigate the possibility of using AASHTO method in order to maintain comparable industry standard.

1.2 Objective

The main objective of this study is to compare the CBR values measured according to VTM and AASHTO procedures, respectively. The significance of any difference, if any existed, also needs to be investigated. The other objectives are as follows:

- Identify the factors that may affect the CBR results as measured by VTM and AASHTO procedures
- Develop recommendations so as to get a comparable CBR value from VTM and AASHTO methods.

1.3 Scope

The major factors influencing the CBR values measured by VTM and AASHTO methods were evaluated at Central Office (CO) Soils Laboratory (at Elko) with only one source of soil from Fredericksburg District. In addition to these samples, three other district laboratories participated in the direct comparison of CBR values measured with VTM and AASHTO procedures.

2.0 COMPARISON OF TEST METHODS

Although the CBR test is one of the most widely used tests for evaluating subgrade support value, there are variations in the procedure followed by different agencies. In addition to agency specific standards, ASTM and AASHTO have developed standards over the years. The Virginia Department of Transportation mostly follows the AASHTO standard with some modification as stated in the standard Virginia Test Method-8 (VTM-8). Both AASHTO and VTM are primarily intended to determine the CBR value of soil and soil-aggregate having a maximum particle size of less than ¾". VTM does not have any separate procedure for soils having particles larger than ¾"; it follows AASHTO recommendation. Some of the major modifications of the AASHTO method incorporated into VTM are discussed below:

2.1 Equipment and Accessories

The size of the mold used in VTM and AASHTO procedures is different. Although the diameters are same, there are differences in heights as summarized in Table 1. The height of the spacer disk in AASHTO method is 2.416-inches which produces a compacted sample with a net height of 4.584 inches. It is important to note that the height of the compacted sample from moisture-density relationship test procedure (Proctor: T 99 or Modified proctor: T 180) is also same as AASHTO CBR test (4.584 inches). On the other hand, VTM uses 6” and 7” molds with 1” and 2” spacer disks, respectively. Therefore, the net sample height is 6 inches for VTM method compared to 4.584 inches in AASHTO. This difference in height of the sample may affect measured CBR values.

There are minor differences in the height and diameter of swell plate and the size of plate spindles. This may not produce any significant difference in measured soaked CBR values. Although the default surcharge weights are the same in both methods for normal condition, AASHTO allows use of higher loads as desired by the client. Therefore the difference between the two methods for swell potential should be minimal for normal surcharge weights.

Table 1: Differences in Equipment and Accessories Between VTM and AASHTO Methods.

Equipment and Accessories	CBR Test Standard		Remarks
	Virginia Method (VTM-8)	AASHTO Method (T 193)	
Mold Size	Diameter = 6 inches Height = 7 or 8 inches	Diameter = 6 inches Height = 7 inches	
Spacer Disk Height	1 inch Tall for 6”x7” Mold 2 inches Tall for 6”x8” Mold (results in same sample height for both mold)	2.416 inches	
Swell Plate	Diameter = 5.75 inches Thickness = 0.125 inches Perforated but diameter or number of holes are not specified.	Diameter = 5.875 inches Thickness = 0.25 inches Perforated with 42 Holes Hole diameter = 0.0625 inches	If not specified, VTM usually follows AASHTO.
Swell Plate Spindle	Length = 3.75 inches Diameter = 0.375 inches	Length = Adjustable (≈ 4” to 7”) Diameter = 0.375 inches	
Surcharge Weight	Diameter = 5.75 inches Weight = 5 lb Hole at the center; Always uses two surcharges.	Diameter = 5.875 inches Weight = 5 lb May be slotted or split; Usually uses two surcharges.	More surcharges could be used if specified by the client

2.2 Procedure

Although the basic mechanism of measuring CBR value is the same in both VTM and AASHTO methods, there are some differences in the sample preparation techniques as presented in Table 2.

Virginia Test Method (VTM) uses more specific values for moisture content and density for the samples whereas AASHTO allows the user agency to specify these values. Moreover, AASHTO has a provision to conduct the test for a range of moisture contents and densities as requested by the client. The specified value in VTM method is always at optimum moisture content and maximum dry density as determined by VTM-1 (Proctor) method. AASHTO also has the option of running the test at optimum moisture content and maximum dry density as determined by either AASHTO T 99 or AASHTO T 180 method. Even in this situation the samples in AASHTO method are prepared at the optimum moisture content but the CBR value at maximum dry density is interpolated from a range of CBR values measured at different densities. There are some allowable tolerances in VTM with as much as 2 percentage point moisture reduction and dry densities of 97.5% to 102.5% of maximum dry density. Therefore, VTM method is a special case under AASHTO method with suggested tolerances in both moisture and density. The moisture reduction in VTM method is a suggestion to aid in achieving density; it is not required. AASHTO permits moisture-density relationship to be determined using both Proctor (T 99) and Modified Proctor (T 180) as determined by the client but the VTM method only allows Proctor (VTM-1). The difference between Proctor methods according to AASHTO (T 99) and VTM (VTM-1) is in the corrections applied for oversize materials. VTM requires correction when more than 10% materials retain on #4 sieve whereas AASHTO recommends correction for more than 5% oversize (retained on #4 sieve) materials unless specified otherwise by the client. The correction needed for oversize materials between 5 to 10% is small enough to not have any significant effect on CBR value. AASHTO T 99 has four different variations of the procedure to conduct the Proctor test depending on the particle sizes of the sample. If none of the methods is specified by the client, AASHTO suggests Method A, which is exactly same as VTM-1 with the exception of correction as mentioned above. In addition to using a 4" mold for moisture-density relationship, only AASHTO allows use of 6" mold. Although use of 6" mold would give better representation of actual field condition, it would require significantly more soil than 4" mold.

Table 2: Differences in Sample Preparation and Test Procedure

Sample Preparation Techniques	CBR Test Standard		Remarks
	Virginia Method (VTM-8)	AASHTO Method (T 193)	
Compacted Sample	Height = 6 inches Diameter = 6 inches	Height = 4.584 inches Diameter = 6 inches	
Number of Layers	3 (Three) Lift thickness = 1.2 inches	5 (Five) Lift thickness = 1.528 inches	
Number of Blows per Layer	45	Variable (depends on density requirement)	
Moisture-Density Relationship	VTM-1 (Proctor method similar to AASHTO T-99)	AASHTO T-99 (Proctor) or T-180 (Modified Proctor) as specified by the client	
Moisture	Optimum with a maximum of 2% cutback recommended	Client specified – Optimum or a range around optimum	
Density	Maximum dry density	Client specified – Range	
Number of samples	One for each of soaked and unsoaked sample	At least 3 samples for soaked or unsoaked condition**	

** AASHTO also allows using one sample but the required compactive effort to achieve the target density has to be known.

There are also differences between AASHTO and VTM method in compaction techniques and efforts. VTM uses five (5) layers compared to three (3) layers in AASHTO to compact the sample in the mold. The compaction effort is fixed in VTM as 45 blows per layer whereas AASHTO controls the compaction effort by satisfying the dry density requirements. Since the mold heights are different, the lift thickness would be an important factor for relative compaction. VTM uses thinner lifts of 1.2" compared to 1.528" in AASHTO method. It is understandable that a thinner lift would get better compaction than a thick layer with same compactive effort. Thinner lifts may achieve higher density and at the same time would be more uniform. Therefore, factors such as sample height, number of layers, blows per layer, density and water content need further investigation for a meaningful comparison of VTM and AASHTO methods of CBR test.

In the VTM-8 method only two samples are required: a soaked and an un-soaked CBR value. On the other hand, AASHTO procedure requires at least three samples for either soaked or un-soaked condition. For normal production samples, Note 6 in AASHTO allows for nearly the exact same procedure as VTM-8, one sample may also be used in AASHTO procedure but the required compactive effort in achieving the density has to be known beforehand (may be from experience).

2.3 Data Interpretation and Reporting Requirements

The CBR value is calculated as a ratio of load required for 0.1” penetration (usually 1st-0.1”) over a standard load of 3000 lbs. Although there are some apparent differences between VTM and AASHTO data interpretation, both VTM and AASHTO use a load versus penetration relationship to calculate representative load for 0.1” penetration. A correction is sometimes necessary to account for possible piston friction, sample surface irregularities and non-uniformity at the top portion of the sample. These factors may result in penetration without adequate resistance from the sample. Such influences are evident in load versus penetration curve with a reverse curvature at the beginning of the plot. In AASHTO method, the origin is shifted to an amount necessary to eliminate the initial reverse curvature portion of the curve to account for such effects. On the other hand, VTM method calls for such correction by taking the greatest slope over any 0.1” penetration up to a total of 0.2” penetration. VTM also shifts the origin but with fixed increments corresponding to some specified data points since it does not use the plot to make the correction. In addition, correction is not applied in VTM method unless a large change in slope is observed. Although AASHTO method seems more sensitive and extensive, the difference between these two methods should be minimum.

The reporting requirements are different for these two methods because of differences in the procedures as discussed above. Both VTM and AASHTO methods have their respective default sets of requirements for reporting as presented in Table 3. In AASHTO method, CBR value for all the specimens need to be reported without any final interpretation. This may include both soaked and unsoaked as requested by the client. The procedure in general calls for at least three samples for each of soaked and unsoaked condition. On the other hand, the reporting of both soaked and unsoaked CBR is defaulted in VTM method but only one sample is tested for each condition. The moisture content and dry density are reported for every sample tested for CBR in both methods. In addition to these, VTM method also requires reporting wet unit weight and moisture content of unsoaked specimen and soaked specimen before and after soaking. Although optimum moisture content and maximum dry density is determined in both methods, only VTM method requires it to be reported.

Table 3: Difference in Data Interpretation and Reporting Requirement

Data Interpretation and Reporting Requirements	CBR Test Standard		Remark
	Virginia Method (VTM-8)	AASHTO Method (T 193)	
Correction for initial settlement (penetration)	Shifts the origin to some specified points in case of irregular initial settlement	Shifting of origin is based on actual load versus penetration plot	** Elaboration Needed.
Compaction Effort (number of blows per layer)	Since it is fixed for all samples, does not need to be reported	Required to be reported for all samples	
Moisture-density relation	Optimum moisture and maximum dry density	No report requirement	
Moisture content and dry density (percent of maximum)	Unsoaked specimen, and soaked specimen before and after soaking	All specimens tested for CBR	
Wet unit weight	Unsoaked specimen, and soaked specimen before and after soaking	Not required	
CBR	Both unsoaked and soaked required	As requested by the client	
Percent Swell	As a percent of respective sample height	As a percent of respective sample height	

** Detailed discussion is included within the text of this article.

3.0 VARIABILITY OF TEST METHOD

Every laboratory test method has inherent variability that can't be avoided in a standard condition. The precision and bias statement in any standard test method usually addresses such issues. Unfortunately such a statement is not available in either VTM or AASHTO method. But some of the variability for both VTM and AASHTO methods could be estimated from other available sources. There are two types of variability considered for any test method: within-laboratory (single operator) and multi-laboratory. The within-lab variability measures the repeatability characteristics and multi-lab variability defines the reproducibility of a test method in different laboratories. In this study, replicate samples are tested in the same laboratory to compare VTM and AASHTO methods. Therefore, only the within-lab component of variability may influence this study results.

The variability of AASHTO method is estimated from AMRL proficiency data available at ARML's website (www.amrl.net). The single operator (within-lab) coefficient of variation for samples from the last several years is presented in Figure 1. The coefficient varies from 13% to 22% with the exception of a few values.

For the last several years, the Virginia Department of Transportation also conducted a round robin study similar to AMRL proficiency tests for VTM method of CBR testing. Unfortunately it was not designed to measure within lab variability. Different VDOT districts and several private laboratories have participated in this study. As required by VTM method, both soaked and unsoaked CBR were measured. The results are presented in Figures 2 and 3, respectively. From these data multi-lab variability was estimated as shown in Figure 4. In general it varies from 17% to 38% over several years. Single operator/within-lab variability will be much smaller than these values and may be comparable to AMRL data.

The ASTM standard for CBR testing also provides some measure of variability. The within-lab variability is estimated to be 8% but it is based on measurements of seven replicate samples from one source in one lab.

The variability of VTM and AASHTO methods are comparable as discussed above and summarized in Table 4. Based on the data discussed above, an estimation of single operator/within lab coefficient of variability of 8% may be considered conservative. In that case, CBR measured on two replicate samples by the same operator in the same laboratory within a reasonable time period may statistically (at 5% significance level) vary a maximum of 22% ($8 * 2\sqrt{2}$) of their mean. Such variability of the test method needs to be considered in comparing VTM and AASHTO methods.

Table 4: Variability of Test Methods.

Test Method	***Estimated*** Variability (Coefficient of Variation)	
	Within-laboratory (single operator)	Multi-laboratory
VTM-8	Not Available	Approximate Range: 17 to 38%
AASHTO T 193	Approximate Range: 13 to 22%	Approximate Range: 35 to 91%
ASTM D 1883	8.2% (based on very limited data)	Not Available

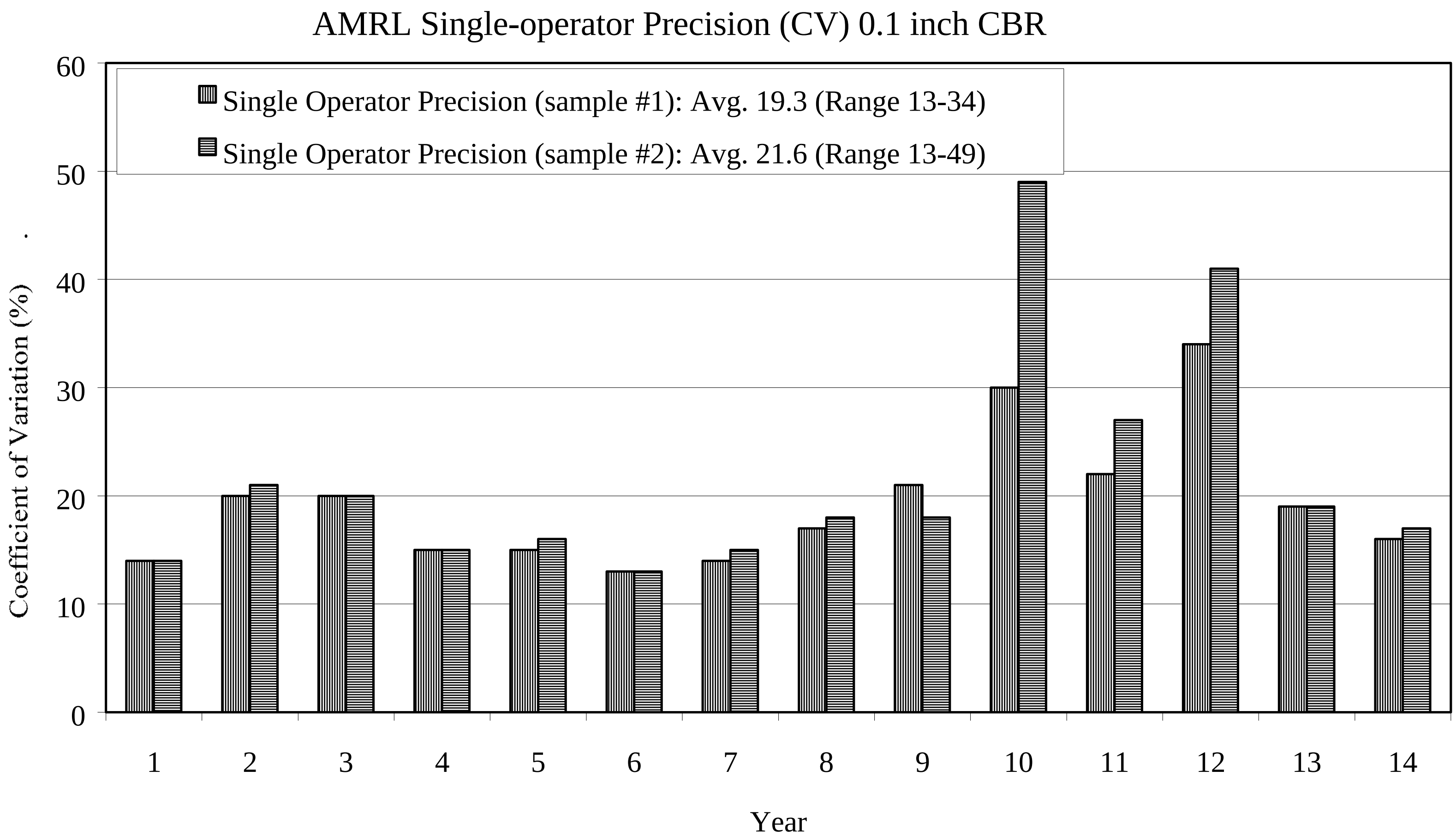

Figure 1: Variability of AASHTO method from AMRL database.

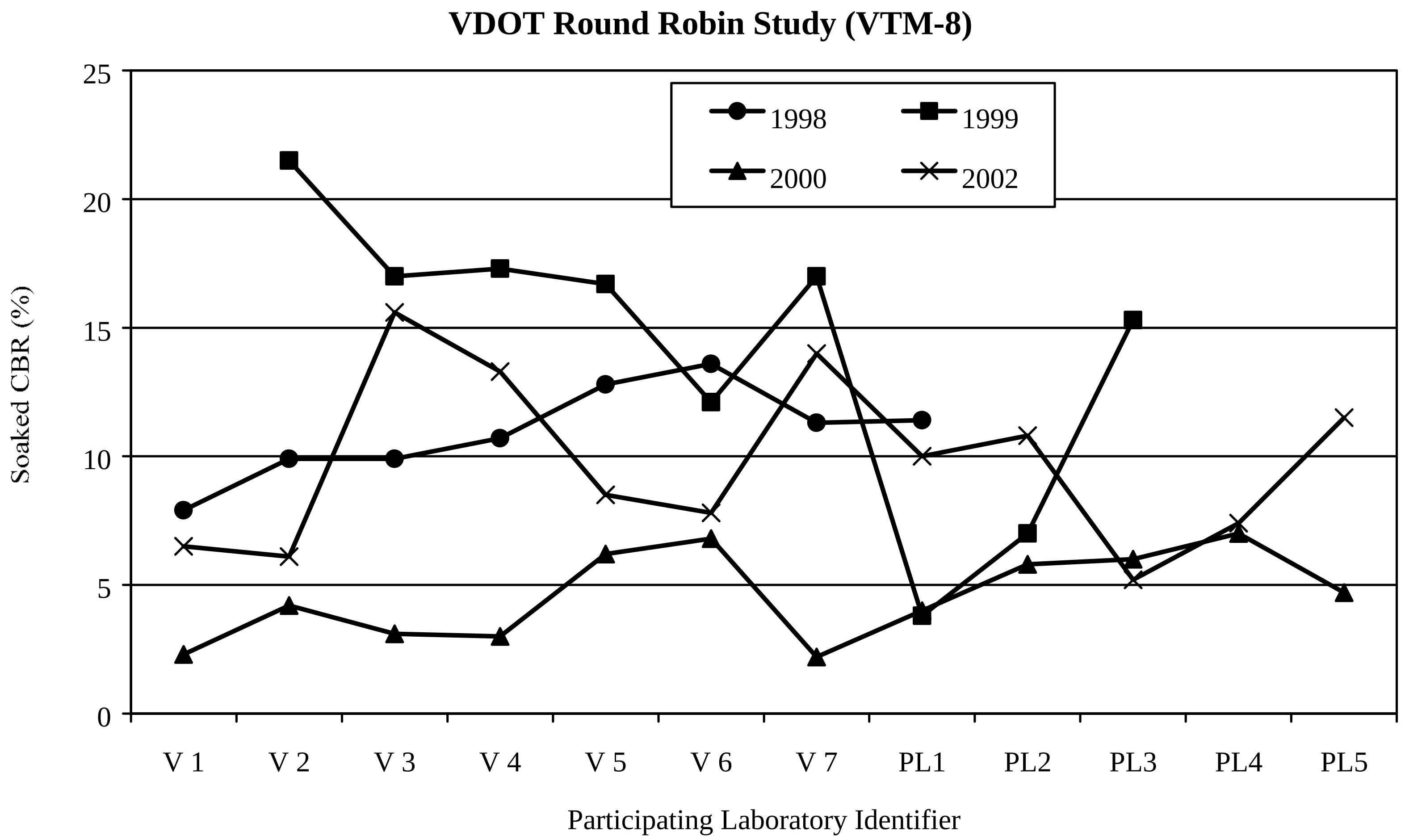

Figure 2: Soaked CBR values from VDOT round robin study.

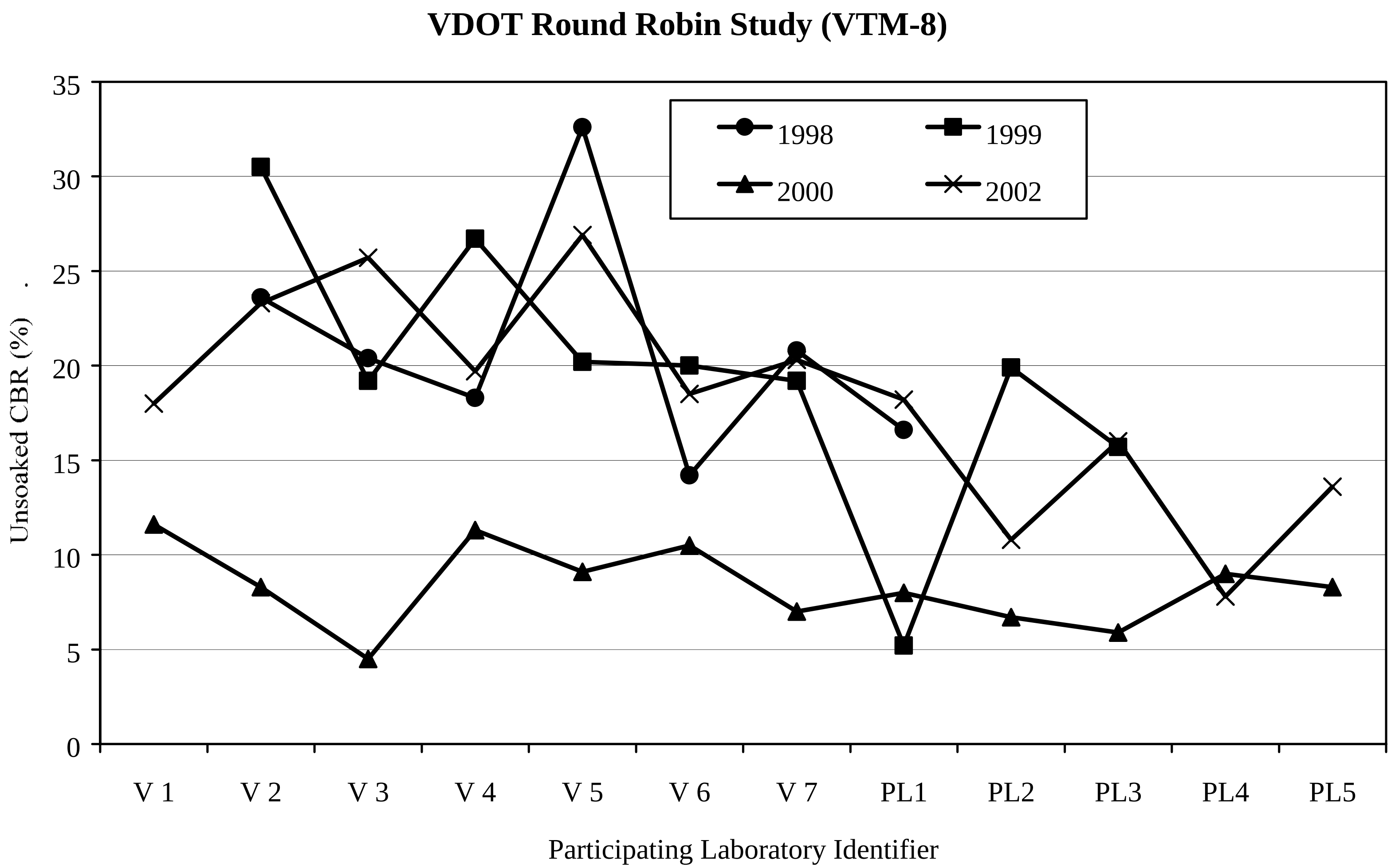

Figure 3: Unsoaked CBR values from VDOT round robin study.

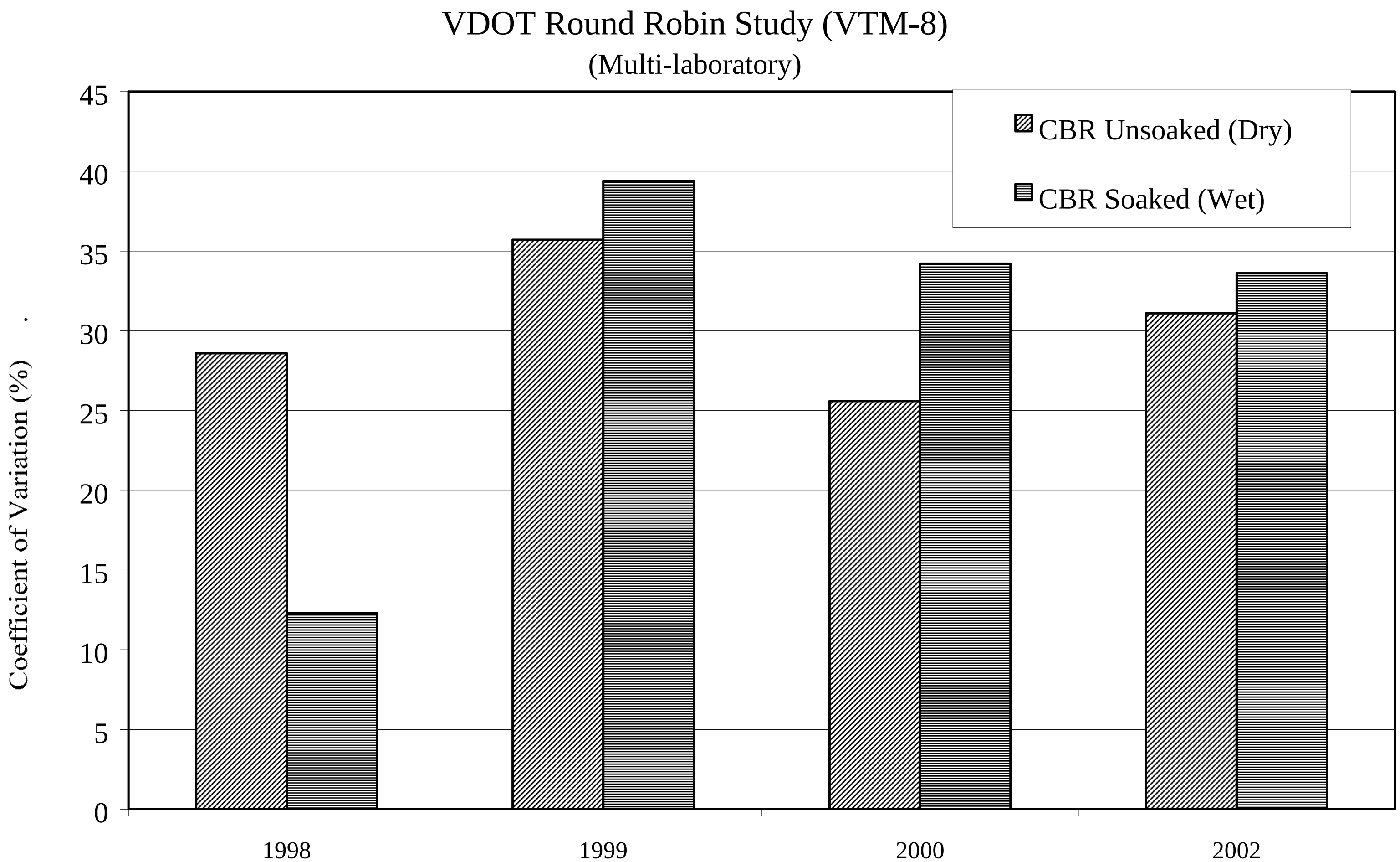

Figure 4: Multi-laboratory coefficient of variation from VDOT round robin study.

4.0 FACTORS INFLUENCING CBR RESULT

As discussed above, there are several key factors such as mold/sample height, compaction effort, etc. influencing the CBR results. These factors may produce a significant difference between the final CBR values from VTM and AASHTO methods. An experimental program as shown in Table 5 was designed to evaluate these factors. A red sandy lean clay soil sample from Stafford County of Fredericksburg District was used for this experimental evaluation. The variables considered in the experimental design were mold/sample height, number of layers and number of blows per layer. The optimum moisture content and maximum dry density were determined using VTM-1 method which is essentially same as AASHTO T 99 for this particular soil because of 100% passing #4 sieve. The soil properties are presented in Table 6. As suggested in VTM-8 method, all samples were compacted at approximately 1.6% below the optimum moisture content and only unsoaked condition was used to measure CBR values.

Table 5: Experimental Program to Evaluate Factors Influencing CBR Results.

Variables:

Mold Type:	VTM and AASHTO
Compaction Effort (Total blow count):	120, 225 and 270
Number of Layers:	3 and 5
(2x3x2 = 12 samples, no replicates)	

Total Number of Blows	Number of Layers	Blows per Layer	Mold Type	
			VTM	AASHTO
120	3	40	Sample 1	Sample 2
	5	24	Sample 3	Sample 4
225	3	75	Sample 5	Sample 6
	5	45	Sample 7	Sample 8
270	3	90	Sample 9	Sample 10
	5	54	Sample 11	Sample 12

Table 6: Soil Properties for Experimental Program

Soil Properties	
District	Fredericksburg, VA
County	Stafford
Color	Red
Visual Classification	Red Clay w/ fine sand & trace silt
Percent passing no. 4	100
Percent passing no. 200	55
Specific Gravity	2.765
Liquid Limit	35
Plasticity Index	16
Unified Soil Classification	CL (Sandy Lean Clay)

To incorporate the variation in sample height, both VTM and AASHTO molds were used to prepare the samples. Use of VTM and AASHTO molds produced sample heights of 6" and 4.584", respectively. Although VTM method allows both 7" and 8" mold, a 7" mold was used for this comparison. The number of layers to fill the mold was another variable used in this experiment. The samples were compacted at both 3-layers and 5-layers as done in AASHTO and VTM methods, respectively. As required in AASHTO method, three levels of compaction effort were used to prepare CBR samples with total blow counts: one of them being same as VTM method; this scheme covers both VTM and AASHTO methods for a relative comparison. The total number of blows for each compaction effort was distributed evenly on 3 layers and 5 layers as needed.

Samples were prepared and tested in the CO Soils Lab at Elko. Although the use of replicate samples was planned, only one sample for each combination was tested due to shortage of soil. The results of CBR tests are summarized in Table 7. It is important to note that none of the samples needed any origin correction as explained earlier (in data interpretation section).

Table 7: CBR Test Results for Laboratory Experiment at CO Soils Lab.

Sample No.	Test Procedure	Compaction		Sample Density (% Optimum)	Water Content (%)	CBR (%)
		Number of Layers	Blows per Layer			
1	VTM	3	40	86.8	10.2	14.2
2	AASHTO	3	40	87.6	10.2	13.3
3	VTM	5	24	86.3	10.5	13.7
4	AASHTO	5	24	94.8	10.5	16.6
5	VTM	3	75	91.1	10.2	23.7
6	AASHTO	3	75	94.8	10.2	25.0
7	VTM	5	45	92.6	10.5	22.3
8	AASHTO	5	45	94.7	10.5	25.8
9	VTM	3	90	91.3	10.2	22.0
10	AASHTO	3	90	95.9	10.2	25.8
11	VTM	5	54	94.6	10.5	28.3
12	AASHTO	5	54	96.3	10.2	32.0

- Moisture-Density relationship according to VTM-1:
    - Maximum Density = 119.6 lb/ft^3 and Optimum M.C. = 12%

In general, higher compacted density should yield higher CBR value. The measured CBR values from this experiment are plotted against the achieved density of the sample in Figure 5. Data are grouped according to mold type (two levels: VTM and AASHTO) and number of layers (two levels: 3 and 5) to fill the mold. Lines for all four combinations in the Figure 5 are close to each other and have positive slopes indicating the expected trend. For a particular density the variation in CBR values for all four combinations is minimal and may well be within the normal variation (22% of the mean) of the test methods. A statistical trend line was drawn through the data. The coefficient of regression (R^2) of 0.9 for the trend line indicates a fairly strong effect of density on CBR value. Two lines with a variation of 22% of mean CBR value based on trend line are drawn on the same plot. All the data points are within the range of these two lines indicating no significant difference between these two methods of measurement for CBR value as long as they are based on density.

One important thing to note here is non-achievement of maximum dry density despite high compaction effort in both methods. Cutback on moisture content from optimum may account for this low density but such a small amount of reduction in moisture content should not have any significant effect in the relative comparison between these two methods.

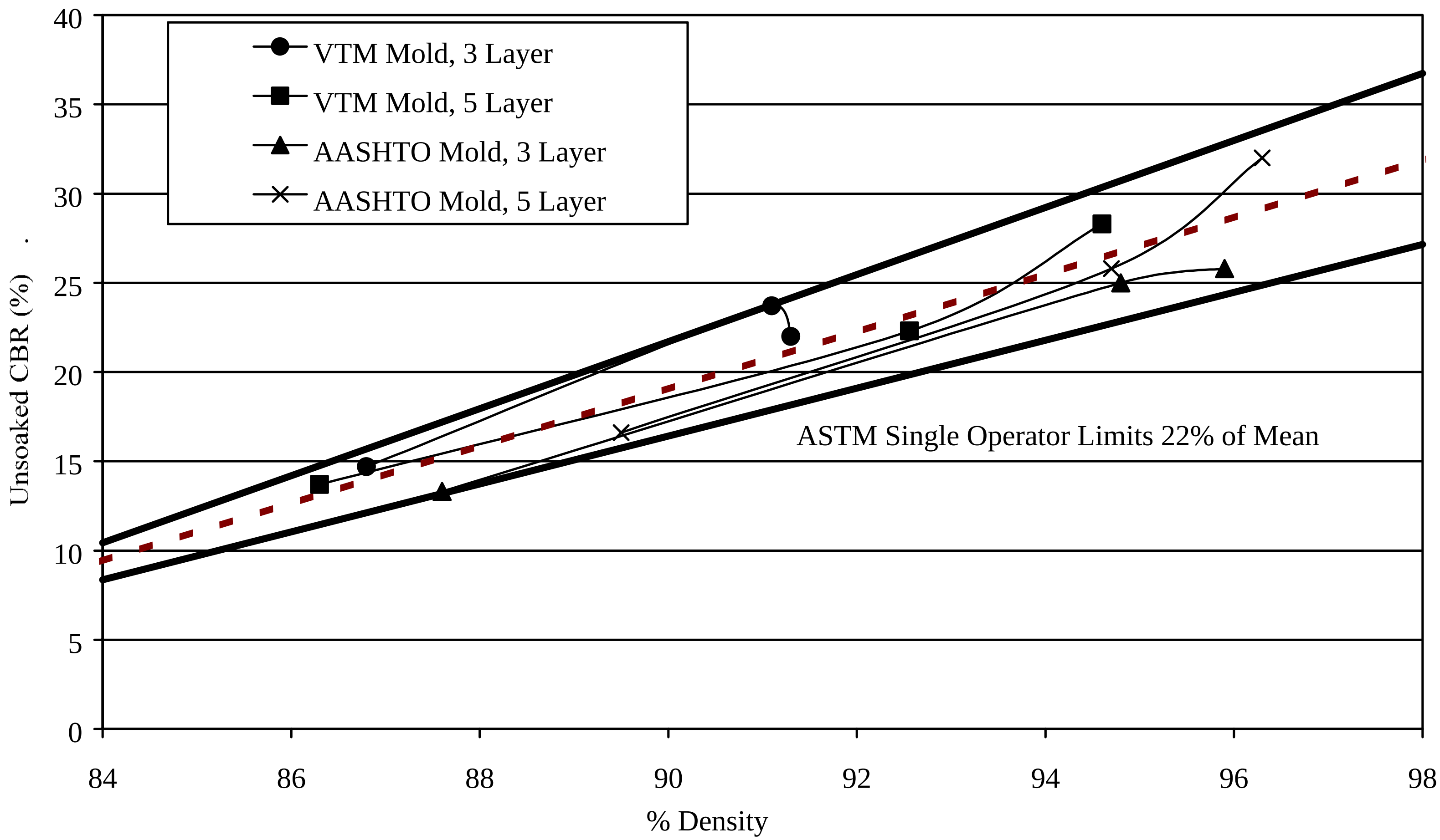

Figure 5: Variation of CBR values with sample densities in the laboratory experiment.

5.0 DIRECT COMPARISON OF CBR RESULTS

The next step in the study was to make a direct comparison of CBR values measured by VTM and AASHTO methods for a variety of soils encountered in the Commonwealth of Virginia. Such a comparison will give an assessment of the impact of using AASHTO method in place of VTM method.

In order to compare the results obtained by these two methods, different districts of VDOT have conducted soaked CBR tests using both procedures. CBR values are presented in Table 8 along with other pertinent information such as brief description of soil, optimum moisture content, maximum dry density, density of tested sample and so on. Both density and moisture content were controlled between the comparison samples to minimize their effect on the CBR result. A total of 12 samples covering range of materials were included in this comparison test. In addition to CO Soils Lab at Elko, three other district laboratories participated in the program.

In order to achieve a meaningful result by comparing only a limited number of samples, a statistical approach was taken. Since most construction material properties are normally distributed, we can assume our CBR results from both test procedures are also normally distributed. Any normally distributed population can be described uniquely by two parameters: mean and variance (standard deviation). Therefore, the variance and mean of these two populations (VTM-8 and AASHTO T 193) were statistically compared using F and t tests, respectively. The statistics for both F and t tests such as mean, variance and probability are included in the Table 9. The probability of F-statistics is 0.2, which indicates that there is no significant difference between the variance of VTM-8 and AASHTO T-193 at 95% confidence level. Similarly, the probability of T-statistics for both equal and unequal variance cases is 0.4. Again, this shows there is no statistically significant difference between the means of the two procedures at 95% confidence level. Therefore, it can be concluded with 95% confidence that the CBR measurements by VTM-8 and AASHTO T-193 represent the same population, i.e. there is no significant difference between these two procedures as long as the sample density and moisture content are the same. Moreover, AASHTO values are lower than VTM in 8 out of 12 cases as shown the Figure 6. Therefore, AASHTO values were conservative compared to VTM values.

6.0 CONCLUSIONS AND RECOMMENDATIONS

As mentioned above, California Bearing Ratio (CBR) is a test widely used to evaluate soil and soil-aggregate support values for structural pavement design. The Virginia Department of Transportation routinely uses this test for pavement design. VDOT uses AASHTO test methods with some modification to meet their specific needs. AASHTO also regularly updates their test methods to meet the industry requirement. An in-house investigation was performed to evaluate the effects of additional modification suggested in Virginia Test Method over current version of AASHTO method. There was no significant difference observed between the CBR values measured according to VTM-8 (November 1, 2000) and AASHTO T 193-99 (2003) methods. The following are the conclusions of the comparative study between VTM and AASHTO method of CBR testing:

- The basic differences between VTM and AASHTO methods are sample size and number of layers to fill the mold.
- Both methods were found to be fairly variable but somewhat comparable to each other.
- The differences in sample height, number of layers to fill the mold and compaction effort (number of blows per layer) did not make any significant difference between the CBR values measured with VTM and AASHTO methods, provided density and moisture content of the sample were same.
- There was no statistically significant difference at 95% confidence level between the CBR values measured according to VTM and AASHTO method for several soils from different districts of VDOT. It is important to note that both moisture content and density were kept closer to each other between the samples tested according to VTM and AASHTO methods.
- The CBR values measured with AASHTO method were lower than those of VTM method for 75% of the samples during this study; therefore AASHTO CBR seems to be conservative.

Table 8: CBR Test Results for Direct Comparison.

Sample No.	District	Description	AASHTO Lab Classification	AASHTO T 99 Method A		AASHTO T 99 Method D		Density before Soaking		Soaked CBR Value	
				OM	MD	OM	MD	VTM-8	AASHTO T 193	VTM-8	AASHTO T 193
1	Culpeper	Reddish tan clayey SILT, trace sand and mica	A-7-5(22)	24.20	97.10	22.40	100.00	96.90	98.40	9.60	9.00
2	Culpeper	Olive brown to reddish brown micaceous SILT, trace sand	A-4(0)	17.20	106.20	17.10	108.90	103.60	107.50	4.30	1.50
3	Lynchburg	Red micaceous silt	A-2-5(0)	20.40	99.10			99.20	97.80	4.20	4.3*
4	Lynchburg	Tan micaceous silt	A-2-5(0)	15.10	106.30			99.99	101.70	5.10	7.2*
5	Lynchburg	Yellow tan silt with decomposed stone	A-2-4(0)	14.40	114.20			101.60	102.40	2.70	5.6*
6	Lynchburg	Red silty clay	A-4(4)	24.10	96.80			101.90	99.00	7.40	8.3*
7	Staunton	Red clay	A-6(15)	19.60	105.60			100.68	n/a	5.00	2.27
8	Staunton	Red silty clay	A-6(5)	16.10	113.00			100.69	n/a	10.77	6.10
9	Staunton	Brown silty clay	A-3(0)	15.30	105.20			99.94	n/a	16.13	14.87
10	CO Soils Lab	Red clay	A-7-5(10)	22.00	100.10			98.84	97.17	11.33	6.67
11	CO Soils Lab	Decomposed stone	A-2-4(0)	12.30	117.00			99.45	100.85	22.50	15.83
12	CO Soils Lab	Tan micaceous silt	A-2-4(0)	13.10	103.00			97.55	97.55	7.17	4.17

AASHTO T-99 Method A is assumed unless otherwise noted

*Corrected values

Table 9: Direct CBR Comparison Statistics for F-test and t-test.

F-Test Two-Sample for Variances		
	VTM-8	*AASHTO T-193*
Mean	8.85	7.150833333
Variance	33.0616	19.65122652
Observations	12	12
Df	11	11
F	1.68241916	
P(F<=f) one-tail	0.200797698	
F Critical one-tail	2.817927225	
t-Test: Two-Sample Assuming Equal Variances		
	VTM-8	*AASHTO T-193*
Mean	8.85	7.150833333
Variance	33.0616	19.65122652
Observations	12	12
Pooled Variance	26.35641326	
Hypothesized Mean Difference	0	
Df	22	
t Stat	0.810715452	
P(T<=t) one-tail	0.21310642	
t Critical one-tail	1.717144187	
P(T<=t) two-tail	0.426212839	
t Critical two-tail	2.073875294	
t-Test: Two-Sample Assuming Unequal Variances		
	VTM-8	*AASHTO T-193*
Mean	8.85	7.150833333
Variance	33.0616	19.65122652
Observations	12	12
Hypothesized Mean Difference	0	
Df	21	
t Stat	0.810715452	
P(T<=t) one-tail	0.213310992	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.426621983	
t Critical two-tail	2.079614205	

Comparison of VTM-8 vs AASHTO T-193

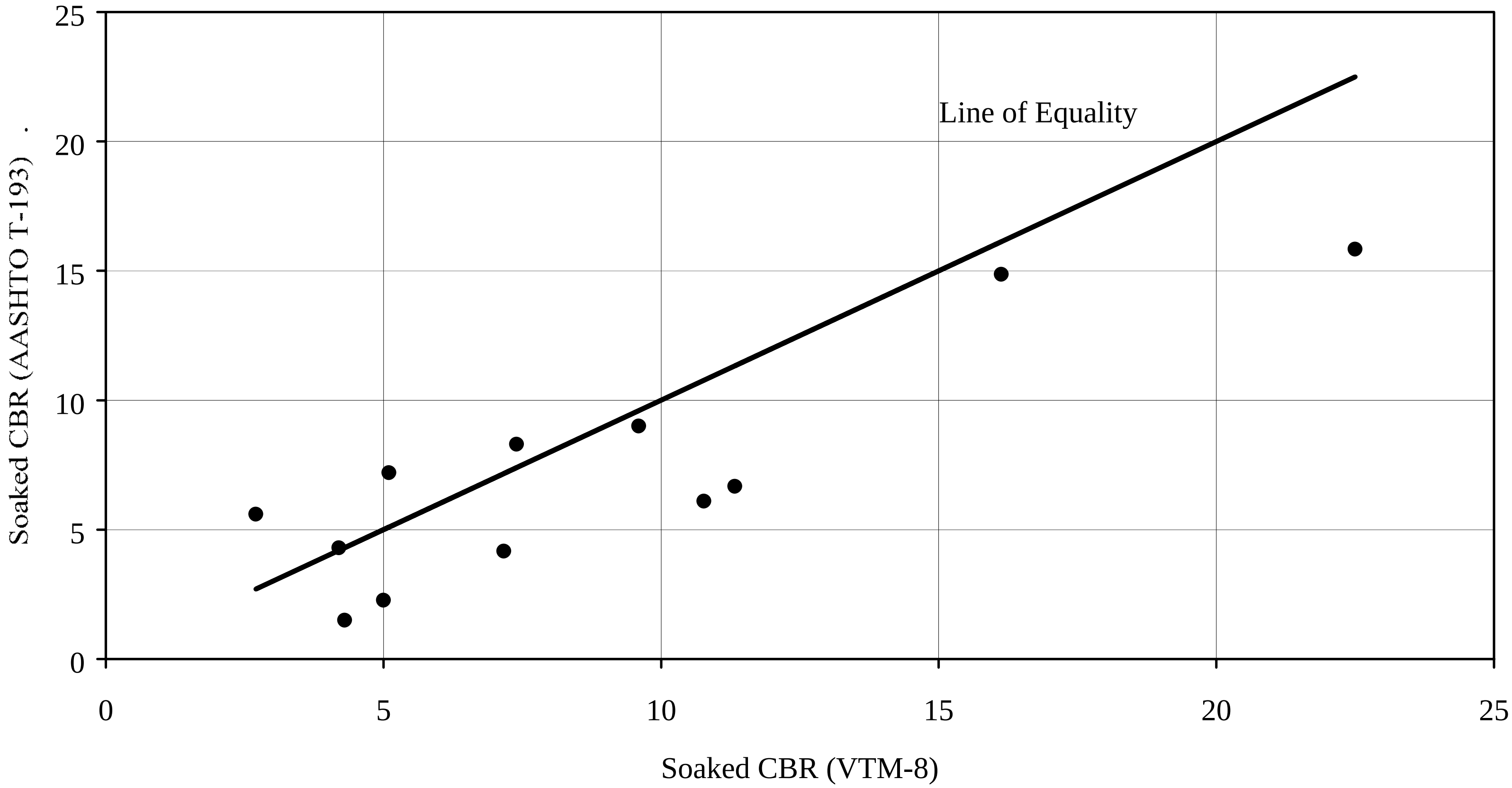

Figure 6: Comparison of CBR values measured according to AASHTO and VTM methods.

It is evident from the study that the current version of AASHTO method [T 193-99 (2003)] for CBR produces equivalent results to VTM-8 method. Since several parameters for sample preparation and testing in AASHTO method are client specific, VDOT districts should specify those as a client in order to get comparable results. The following are the recommended practice:

- Moisture-density relationship should be determined using AASHTO T 99 (Proctor) Method A, which is default in AASHTO method. Additional comments:
    - Use of Method D may represent the field condition better since it uses bigger mold but would need more materials.
    - Moisture correction for oversize materials is defaulted at 5% in AASHTO method instead of 10% in VTM.
- All samples should be prepared at optimum moisture content. (Moisture cutback in VTM is only recommended to aid in achieving density but it is not required.)
- CBR values are required at densities ranging ±2.5% of maximum dry density.
- The respective districts should specify the requirements for soaked and/or un-soaked CBR. If needed they should also specify the swell requirement.
- Surcharge weight should be specified; default weight is 10 lb.